Rep-Rated Z-Pinch Power Plant Concept

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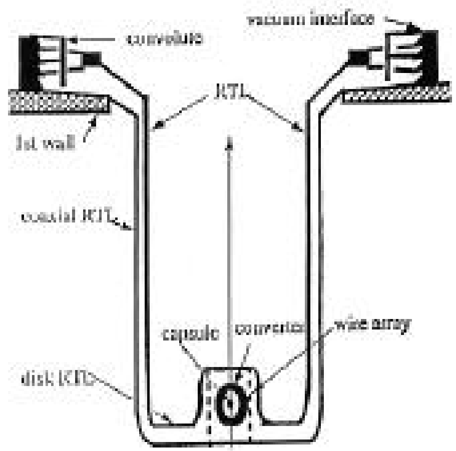
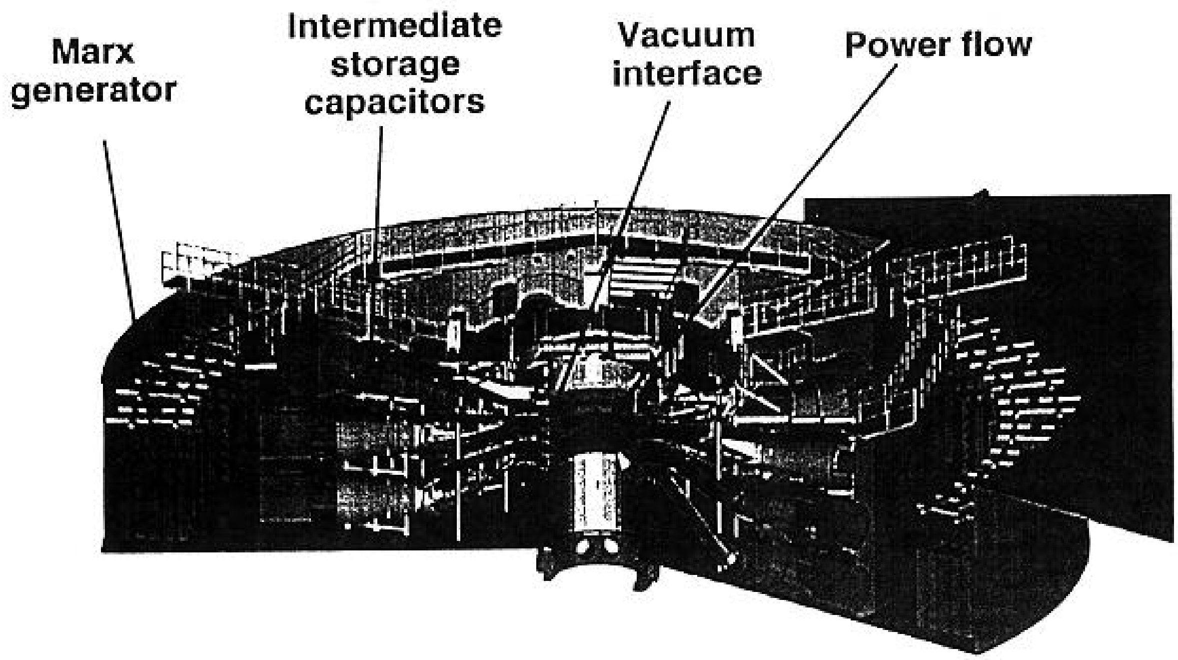
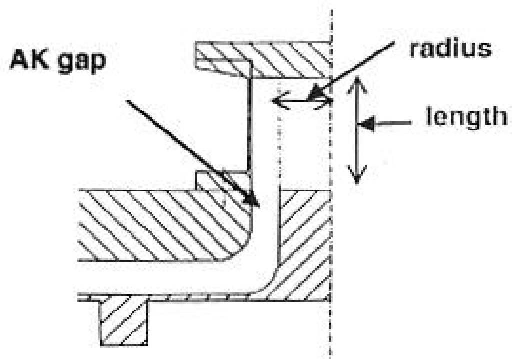


Innovative Confinement Concepts Workshop
Lawrence Berkeley National Laboratory
Berkeley, CA 94720
February 22-25, 2000

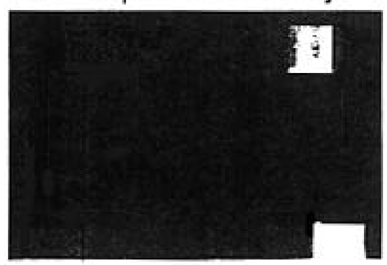
Z is the most powerful multi-module synchronized pulsed power accelerator in the world



A fast z pinch converts electromagnetic power into x rays



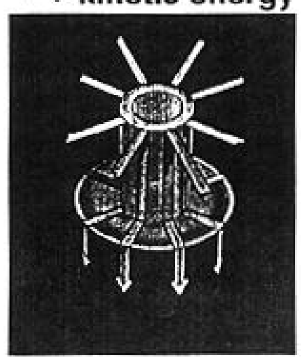
240 10 μm W wire array



- Initial diameter: 17.5 to 50 mm
- Initial length: 7.5 to 20 mm
- Wire diameter: 5.1 to 15 μm
- Wire number: 120 to 300 wires
- AK gap: 1.5 to 5 mm
- Materials: Al, Ti, Fe, W
- Positional tolerance: 50 μm

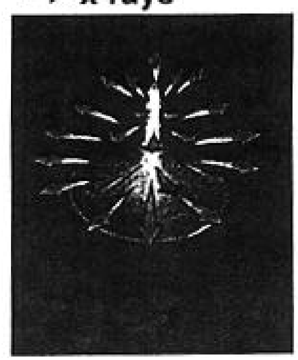
Initiation

Electrical energy
→ kinetic energy



Implosion

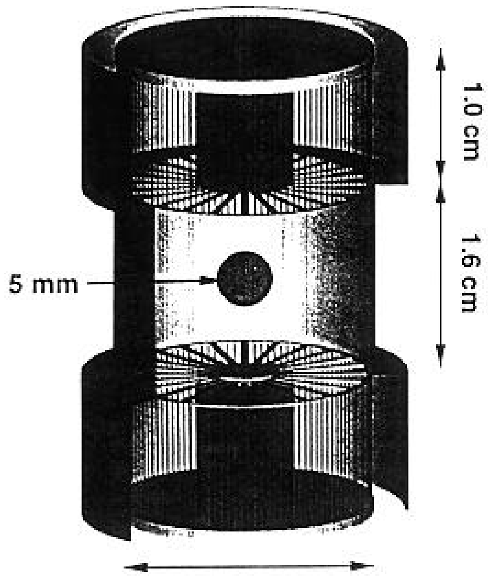
Electrical + kinetic energy
→ internal energy (shock)
→ x-rays



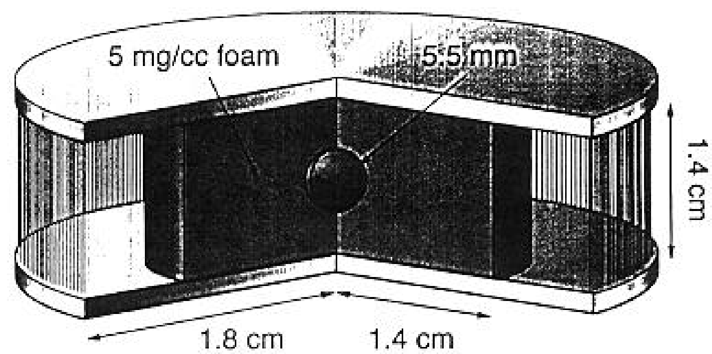
Stagnation

The Sandia ICF program is currently pursuing two Z-pinch based high yield concepts.

Z-pinch Driven Hohlraum



Dynamic Hohlraum



Yields: 400 MJ - 1200 MJ

Abs. Energy: 1 MJ - 2.5 MJ

MFE-IFE Technical Workshop
Princeton Plasma Physics Laboratory
Princeton, NJ 08543
September 14-16, 1998

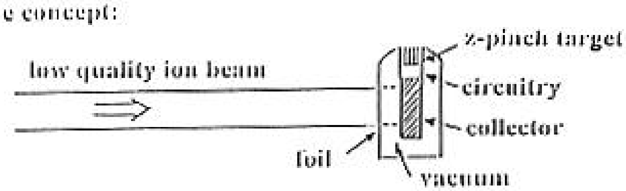
Concepts for rep-rated, indirect drive, z-pinches for IFE are just beginning to be proposed

category 1: very high yield (~10 GJ), low rep-rate (~0.1 Hz)

category 2: low mass or liquid Li electrodes

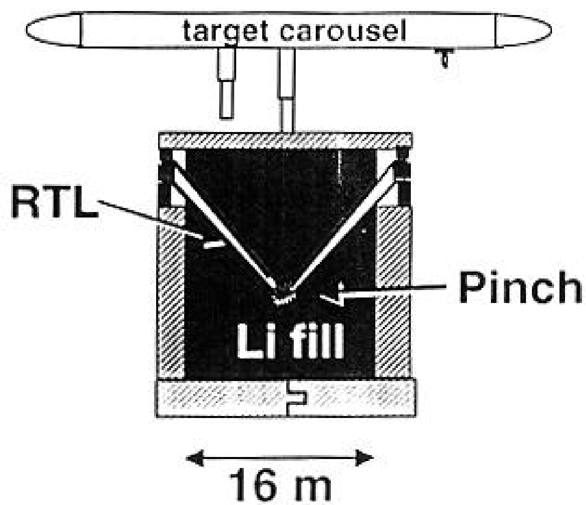
category 3: electron beams, ion beams, or high-velocity mass to power convertor/z-pinch target

crude concept:



The MFE/IFE fusion energy community is invited to help develop IFE concepts for z pinches

Rep-Rated Z-Pinch Power Plant Concept



- *Robust environment (metal and plastic)*
- Recyclable transmission line (RTL) made of solid Li or FLiBe
- RTL's pumped down before loading
- No Chamber pump-down requirement
- Can pack solid or liquid Li or FLiBe
  - for tailored density profile to
  - mitigate shock
- Wall lifetime limited by shock -
  - not neutron damage

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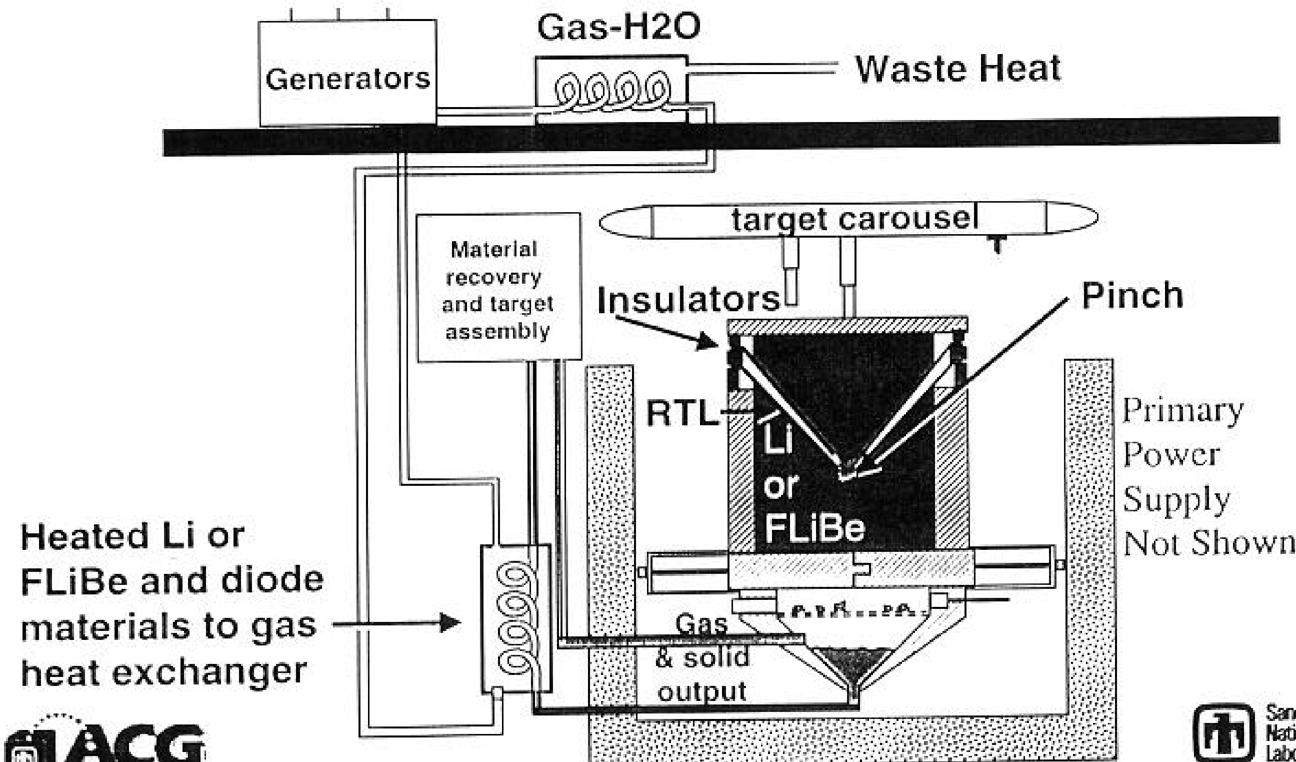
Rep-Rated Z-Pinch Power Plant Concept



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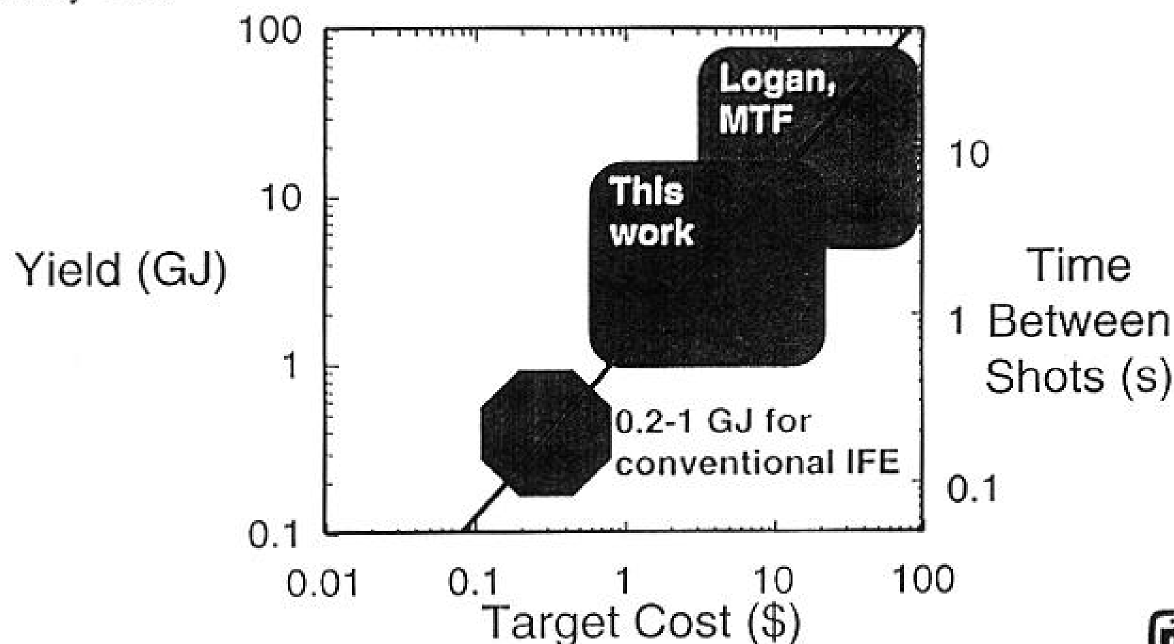
In this ICF reactor design one tradeoff will be rate vs. yield.

$$\text{Time Between Shots} = \text{Efficiency} * \frac{1GW}{Yield} \qquad \text{Target cost} = (10\%)\left(\frac{\$0.05}{kWh}\right)\left(\frac{1kWh}{3.6x10^6\,J}\right)(0.5)Yield$$

Efficiency = 0.5



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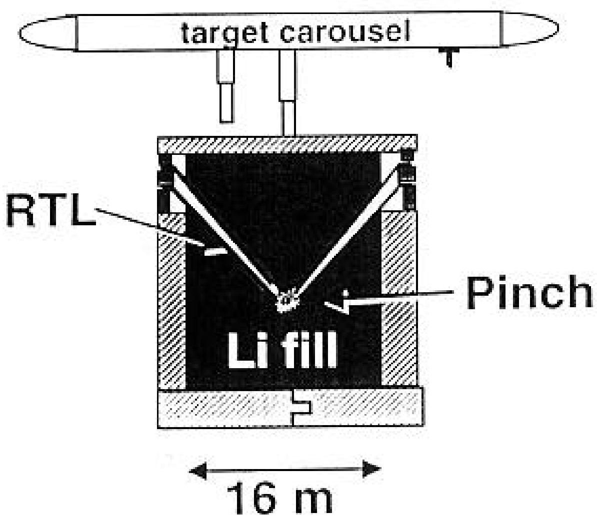
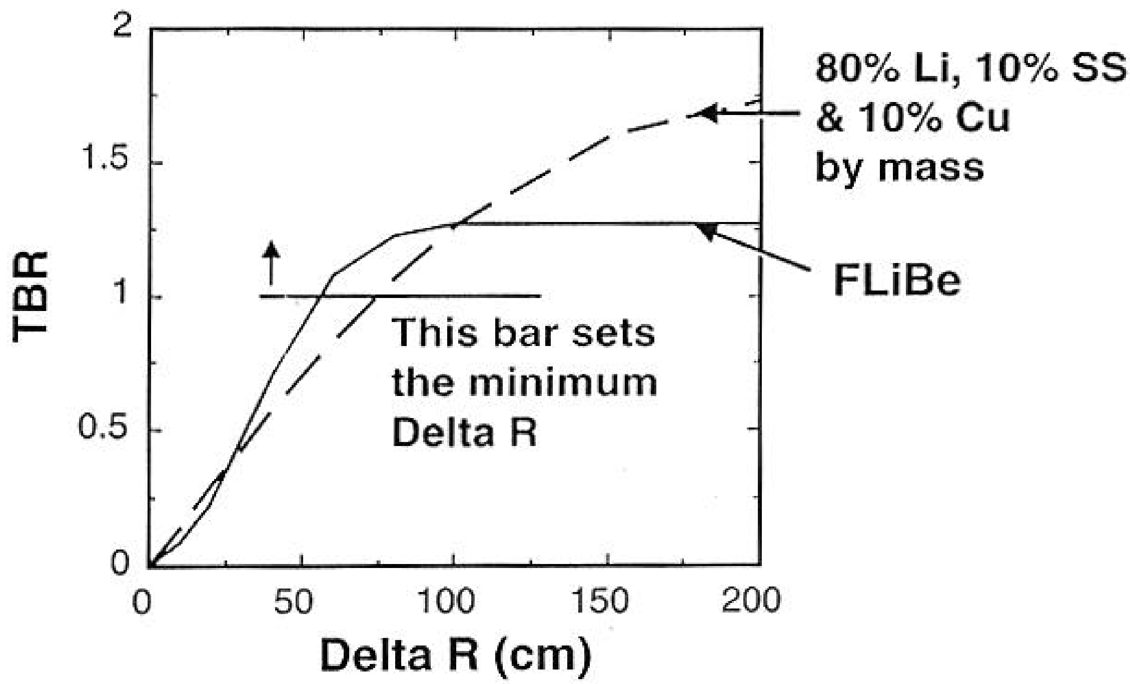
Disposable RTL, i.e. standoff, is affordable with today's technology



- Cost/RTL ~ $0.7
  - Estimate supplied by A. Zamora and P. McKey of the Advanced Manufacturing Group at SNL.
- RTL's pumped down before loading
- 2 mil (50 μm) alignment at convolute
- 40 mil tolerance at insulator

Tritium breeding for simple blanket is very favorable



TBR = tritium breeding ratio

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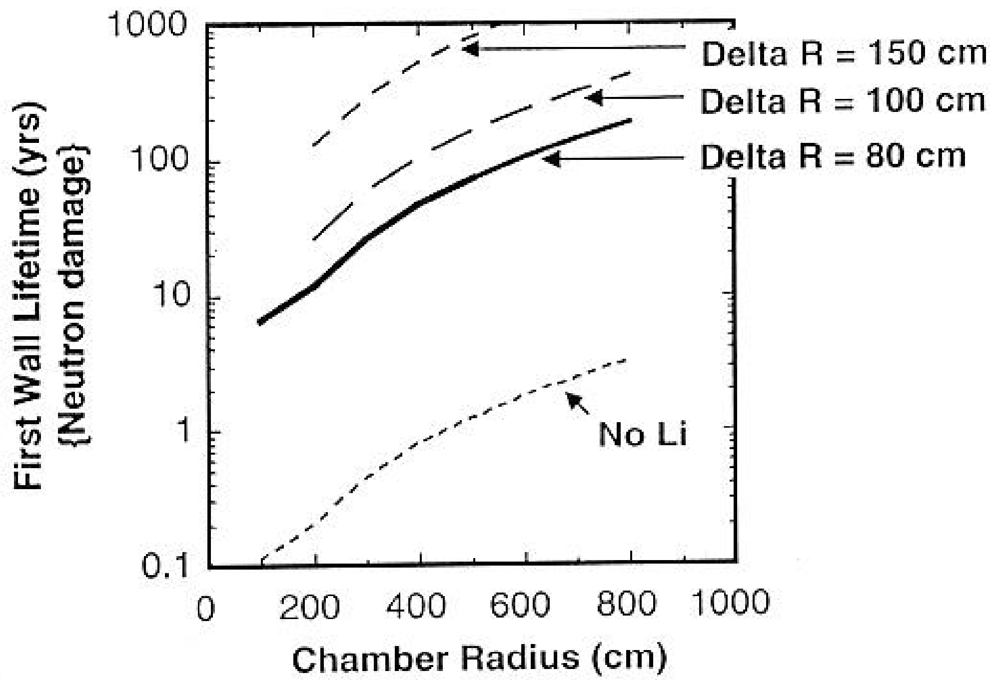
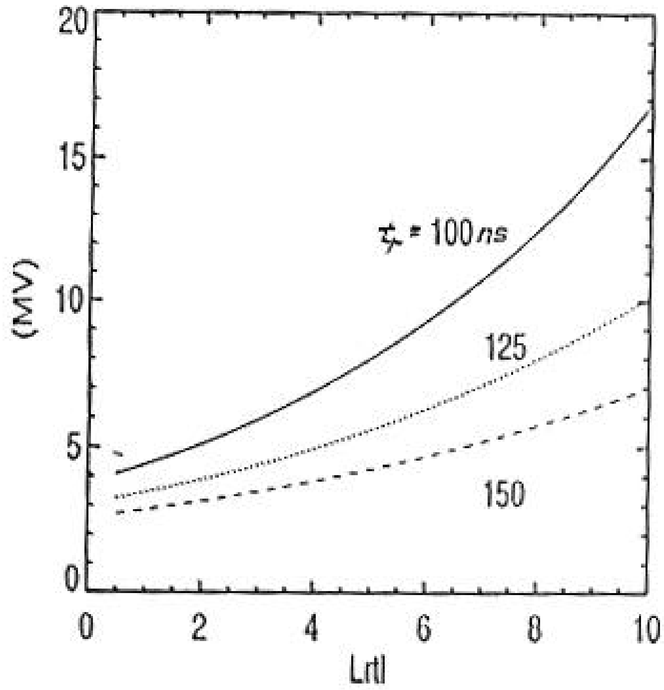
Wall flux sets minimum of confinement vessel size and lifetime

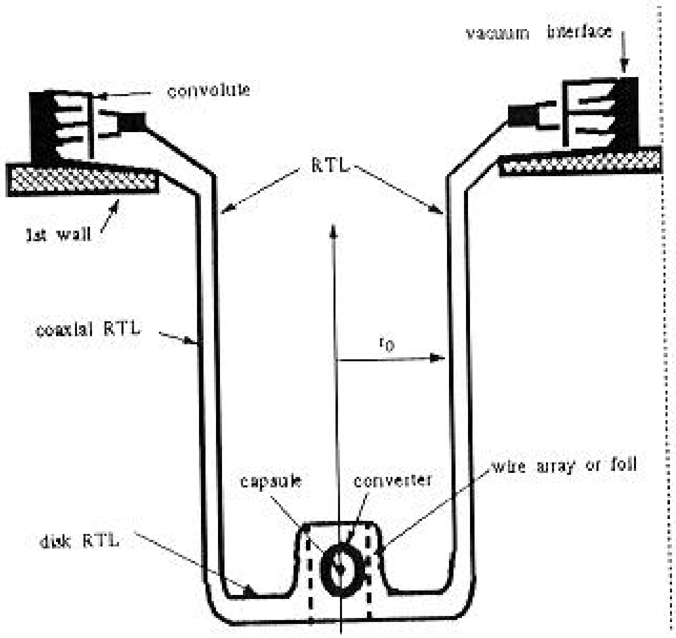


The driving voltage is a strong function of the standoff distance



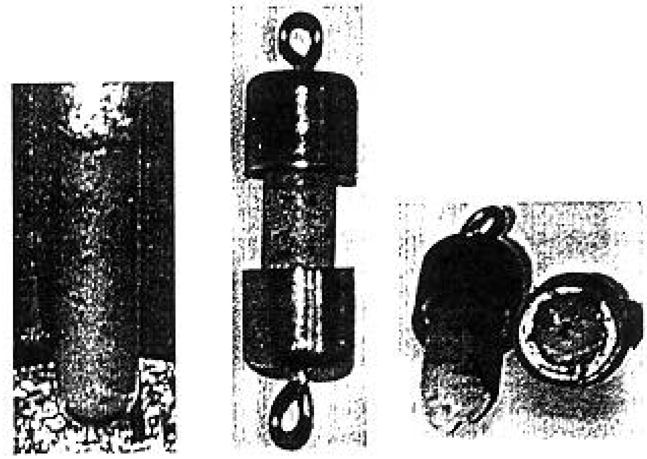
- The RTL dimensions were calculated for self magnetically insulated operation at a peak current of 60 MA
- Per Peterson estimates that 4 m of standoff will be required for GJ yields
- The driving voltage is about 3-4 MV on the Z accelerator with a risetime of 100 ns
- Work on longer pulses is in progress

The RTL can bend around corners, permitting excellent shielding for the convolute and interface



Pulsed Power Can Use Inexpensive Electrodes Cast From Chamber Coolants

- Coolant options include:
  - Lithium
  - Lithium-tin and lithium-lead alloys
  - Flibe salt and tin or lead (binary coolant system)
- Molten flibe is immiscible with tin and lead
  - Cast flibe (T_{melt} = 460 C) can be used as an insulator
  - Tin (232 C) and lead (327 C) can be conductors
  - UCB has fabricated simple, strong cast flibe/metal structures



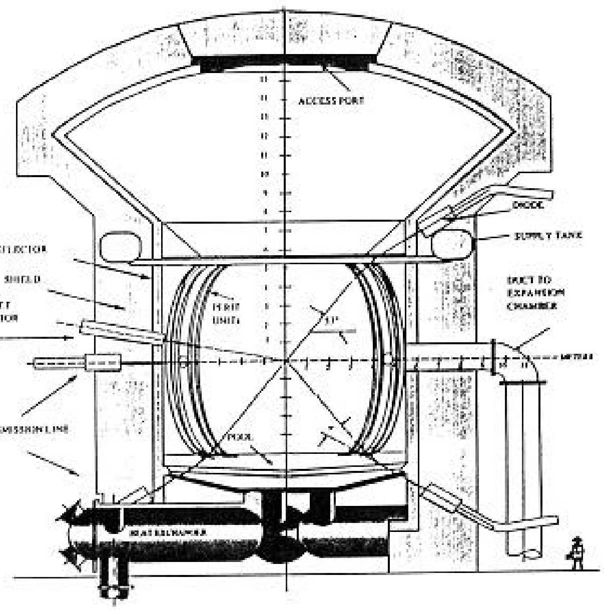
(A) Casting (B) Fabrication (C) Strength Test

1.5-cm ϕ Flibe ingot cast in quartz test tube, tensile test structure fabricated by potting with tin (top) and lead (bottom)

Rep-Rated Z-pinch Target Chamber Design and Analysis will Build on Past Experience

- System Parameters: Power Balance, Balance of Plant Economics.
- Target Output: X-rays, Debris and Neutrons From Fusion Capsule and Z-pinch.
- Magnetic Forces Disassemble Transmission Lines.
- Chamber Dynamics: Fireballs, Fragmentation, Mechanical and Thermal Loading on Permanent Structures.
- Neutronics: Shielding, Neutron Damage, Activation, Tritium Breeding.

LIBRA-SP Target Chamber



Plans for initial feasibility tests

LDRD ($160k) supported by:

VP 1000 (Al Romig) Science & Technology
VP 6000 (Bob Eagan) Energy & Critical Infrastructure
VP 16000 (Gerald Yonas) Advanced Concepts

Proposal to OFES for IFE Concept Exploration Research

Preliminary list of tasks:

- Study RTL candidate materials for electrical and structural characteristics
- Test candidate RTL materials on Saturn
  (Saturn runs at ~ 10 MA and costs ~ $8k/shot)
  (Z runs at ~ 20 MA and costs ~ $60k/shot)
- Fabricate coax RTL from selected material and test on Saturn
- Plan larger tests on Z
- Study shock mitigation for liquid Li or solid Li with voids
- Examine possibility of direct/MHD conversion
- Consider directed venting of targets
- Study effects of fragmentation and debris from RTL/target
- Scope rep-rated pulsed power
- Refine rep-rated z-pinch power plant concept
- Initiate pre-systems study of complete concept

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Summary

- Disposable RTLs affordable
- The whole chamber does not require pumpdown (the RTLs do and they can be pumped before installation)
- Wall lifetime is not neutron damage limited
- Multiple chambers could be used to reduce rate in a given chamber and allow for maintenance
- This dirty environment of steel and plastics can survive shock and debris

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